A

GENERAL REVIEW

OF THE

GEOLOGICAL EFFECTS

OF THE

EARTH'S COOLING

FROM A

STATE OF IGNEOUS FUSION.

BY

JAMES D. DANA.

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A GENERAL REVIEW, &c.

In former papers in this Journal,* the writer has endeavored to illustrate the origin of many of the earth's features, by reference to the necessary consequences of cooling from a state of igneous fusion. In conclusion, a summary of the results arrived at is here offered, in order to aid the reader in a cautious and comprehensive revision of the subject; for its bearing upon the history of our globe is so important and of so universal a character, that it cannot receive too close attention. If there has been a state of igneous fluidity, the cause appealed to has acted; and to reason rightly on many points in geological dynamics, the effects of this prime cause should be first ascertained. Whatever the fact under consideration, be it an elevation, a subsidence, a fracture, earthquakes, igneous ejections, or any of the like operations or their consequences, we cannot be sure of assigning the true explanation, until it is shown whether this grand agency—which commenced with the very beginning of solidification, to end only with cooling itself,—has operated or not in producing or modifying the result. It is much to be desired that mathematical science may give definiteness to our views on this fundamental point in geological theory.†

The hypothesis of the former fluidity of the earth, we have not deemed it necessary to discuss. The proofs of an approximate uniformity of trend in the earth's features, and consequently of a prevailing structure in the very nature of the crust of our globe, place the question almost, if not quite, beyond doubt. The investigations of W. Hopkins, Esq., showing on astronomical data, that the whole is not now solid, afford still stronger confirmation of the hypothesis, and fully authorize the adoption of it as a basis of reasoning.

* Vol. ii, ii Ser., p. 335, and iii, 94, 176. 381, 1846, 1847.

† In this branch of investigation, principles of the highest importance to science have already been deduced, with great ability, by W. Hopkins, Esq., F.R.S. We alluded to his researches on the systems of fissures consequent on elevations, in the last volume of this Journal, pp. 395, 396; and we mention here what escaped us till too late for insertion in that place, that his "Researches in Physical Geology," are continued in a series of articles in the Transactions of the Royal Society, for the year 1839, p. 381, for 1840, p. 193, and for 1842, p. 43, treating especially of the bearing of the amount of precession and nutation on the question of the fluidity of the interior of the earth and the thickness of the crust. Mr. Hopkins argues that the earth could not have cooled at the surface as long as there was perfect freedom of motion in the igneous fluid, and concludes that "the minimum thickness of the crust of the globe, which can be deemed consistent with the observed amount of precession, cannot be less than one-fourth of the earth's radius;" also, that the mean inclination of the earth's axis to the place of the ecliptic, can never have changed since solidification commenced.

It should be remarked, that in the following summary the causes alluded to are not presented as the only source of the effects enumerated, though a legitimate and sufficient source. The causes have acted conjointly with the wide-spread agency of water, yet they may have been less dependent on the latter for many results, than has often been urged. We mention no authorities for any of the conclusions stated, as they are already given, as far as known to the author, in the previous articles alluded to.*

General Review of the Consequences of the Earth's Cooling.

I. Solidification of the surface after the fluid material had lost its perfect fluidity.

a. The change inconceivably slow, and hence the rock formed having a coarsely crystalline texture :—the subsequent progress of solidification *beneath* the crust still more gradual, and therefore producing at all periods of the globe a coarsely crystalline texture :—the whole the result of a single immeasurably prolonged operation.†

b. Hence, probably, a general uniformity in the crystalline structure, sufficient to give the crust apparently two directions of easiest fracture, whose mean courses are N.W. b. W. and N.E. b. N.; yet varying much, being probably dependent to a great degree on the early direction of isothermal and isodynamic lines, (this Journal, iii, 392.)

c. In the progress of this cooling, commencing with its first beginning, the surface necessarily presenting large circular or elliptical areas that continued open as centres of fluidity and eruptive action,‡ (ii, 345; iii, 395.) Subsequently, a gradual reduction in size of these centres of igneous action and their frequent extinction.

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* We add here a reference to the valuable memoirs on slaty cleavage, by W. Sharpe, Esq., in the Quart. Jour. Geol. Soc., No. 7, p. 309, and No. 9, pp. 74–105. See also this Journal, last volume, p. 430, and p. 110, in this number.

See also on the effects of cooling, De la Beche's Report on Cornwall, Devon and W. Somerset, 8vo, London, 1839, p. 33, and elsewhere.

† Long sustained heat of a requisite and scarcely varying temperature, is the essential circumstance demanded for the distinct crystallization of most minerals from fusion. It is well known that lava streams after becoming incrusted over, are often years in cooling. Yet they pass to the cold state too rapidly or irregularly, for a coarse crystallization of all the several ingredients of the rock, and thus illustrate the absolute necessity of the condition stated. We have observed elsewhere, that a granite-like structure is seldom produced about a volcanic vent except in its central mass of lavas where they finally cool, shut out from the air by thick beds of non-conducting rock. (ii, 349.)

We remark farther, that a long-continued uniform temperature, of some specific degree, is a condition of the greatest importance in chemical combination. It is a condition which the Author of nature has established in the animal structure, where the most complex compositions take place. And when the requisite degree of heat in specific cases is ascertained, and the means of sustaining an unvarying temperature are at hand, we may predict that some chemical compositions will be made to take place directly, which now require indirect processes. The reason for this is obvious, if we consider that with difference of temperature is connected difference of size, and difference of attracting power both cohesive and chemical.

‡ Well illustrated on the surface of the moon, as also are many of the points here mentioned, (ii, 335.) See Beer and Mädler's charts.

d. A boiling movement or circulation (up at centre and down around the sides) in the vast circular areas of igneous action, owing to escaping vapors, and dependent mainly on the temperature being greatest below at centre and least at the surface and laterally.* As this circulatory or cyclosis movement occurs in material whose mineral ingredients or products differ in the temperature of solidification or of formation, it determines to some extent the distribution of these mineral constituents, and of the rocks which are formed. In later periods, this cause producing a feldspathic centre to volcanic mountains having basaltic sides, (ii, 343.)

e. As refrigeration went on, the centres of eruption becoming mostly extinct over large areas, and remaining still active over other areas of as great or greater extent:—for cooling, wherever commenced, would extend somewhat radiately from the centre where begun, (yet with some relation to the structural lines,) and so gradually enlarge the solidifying area and encroach upon the more igneous portions.

II. Contraction, as a consequence of solidification, attended by a diminution of the earth's oblateness.

a. Rate of contraction in different parts unequal, according to the progress of refrigeration; and after the formation of a crust, greater beneath the crust than in the crust itself, (iii, 96, 181.)

b. Contraction beneath the crust causing a subsidence of the surface.

c. Subsidence greatest where the crust was thinnest or most yielding, and least in those parts which were thickest from having been first stiffened by cooling;—the large areas that continued to abound in igneous action therefore becoming in process of time more depressed than those areas that were early free (or mostly so) from such action, (ii, 352; iii, 181.)

d. Subsidence of the surface progressive; or, if the arched crust resisted subsidence, a cessation, until the tension was such as to cause fractures, and then a more or less abrupt subsiding, (iii, 96.)

e. Frequent changes and oscillations in the water level, either gradual or abrupt, arising from the unequal progress of subsidence in different parts, and also in early periods from extensive igneous action, (iii, 95, 181.)

III. Fissures and displacements of the crust, owing to the contraction below it drawing it down into a smaller and smaller arc; also, from a change in the earth's oblateness.

a. Fissures influenced in direction by the structure of the earth's crust,—because of the existence of such a structure, and also because

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* The boiling action in Kilauea, Hawaii, appears in general character, closely like that of boiling water. In the great lake, 1500 feet in diameter, there is an active play of jets over the surface precisely as in a boiling fluid, with no sounds ordinarily but the grum murmur of ebullition. A constant flow is seen in the liquid, (well shown in the jets that move with the current,) from the hottest part, near the northeast side, towards the southwest part of the lake; and this flow is so remarkable that it was formerly accounted for by supposing that a submarine stream of fire here came to the surface, and disappeared again after being for a short distance visible.

the tension causing fractures would be exerted with some reference to the structural lines, the tension and the structure being both a simultaneous consequence of cooling, (iii, 394.)

b. Direction of fissures modified by the relative positions of the large areas of unequal contraction, and whatever the actual course, frequently attended by transverse fractures, (iii, 395, 396.)

c. As the force of tension acts tangentially in a great degree, (like the pressure of stone against stone in an arch, and that of the whole arch against the supporting or confining abutments,) the effects will appear either over the subsiding area, or on its borders; and they will be confined to the latter position whenever the surface is strong enough to resist fracture, (iii, 96, 97, 181, 395.)

d. The borders of large subsiding areas sooner or later experiencing deep fissurings and extensive upliftings through the tension or horizontal force of the subsiding crust; these upliftings frequently in parallel series, of successive formation, or constituting a series of immense parallel folds; *that* side of the fold in general steepest which is most remote from the subsiding area, (iii, 98, 182, 186.)

e. Fissures formed having the character of a series of linear rents either in interrupted lines or parallel ranges, instead of being single unbroken lines of great length, and this owing to the brittle nature and structure of the earth's crust; ranges sometimes curved, either from having a general conformity to the outlines of contracting areas, or because proceeding from an inequality of force along parallel lines of tension over a subsiding area,* (iii, 185, 385.)

IV. Escape of heat and eruptions of melted matter from below through opened fissures.

a. Igneous ejection of dikes an *effect* and not a cause of displacements, (iii, 99, 185.)

b. Some points in the wider fissures continuing open as vents of eruption. The outlines of large contracting areas being liable from the cause just stated to deep fissurings, these therefore likely to abound most in volcanic vents, (iii, 98, 186.)

c. Heat from many fissures giving origin to hot springs.

* The writer would remark here, in order not to be misunderstood, that in accounting for curving ranges of elevations, or courses of fissures, by the lateral force of a subsiding crust, (iii, 395,) he has considered the smaller circular areas of igneous action alluded to, as producing scarcely appreciable results, except when combined in large compound areas which subside as a whole. The great curves on the east and northeast of Asia, in the mountains of the continent, as well as in the ranges of islands, are not necessarily due to each being the outline of a circular area of contraction, although we cannot deny that instances of this are possible; but rather to the subsidence that deepened the Pacific depression, and its unequal amount in different transverse lines, connected with the structural character of the crust or its courses of easiest fracture, (iii, 185:)—for these curves are all *convex* alike *towards the ocean*, and similar also are the subordinate curves in the East Indies, (such as that by Negros, West Mindanao and the Sooloo Sea to North Borneo, and that by East Mindanao, Sangir and North Celebes,) as well as the curves in the mountains of Eastern Australia, (iii, 388.)

d. Distribution of the heat attending submarine action, causing metamorphic changes.*

V. Earthquakes, or a vibration of the earth's crust, consequent on a rupture, internal or external, and causing vibrations of the sea besides other effects, (iii, 181.)

VI. Epochs in geological history, (iii, 187.)

VII. Courses of mountains and coast lines, and general form of continents, determined to a great extent by the general direction of the earth's cleavage structure, and the position of the large areas of greatest contraction.

Continents (or areas of comparatively slight contraction) often therefore present ranges of mountains near their borders, and these mountains are highest and abound most in volcanoes around the *largest* ocean, (the Pacific, iii, 398.) Thus the existence of such continental areas determined the existence of the mountains they contain; and also the mountains in their turn, determined to some extent the position and nature of subsequent deposits formed around them, effecting this either directly, or by influencing the courses of ocean currents during partial or entire submergences, or by determining the outlines of ancient seas of different epochs. According to this view, the general forms of continents, and those of the seas, however modified afterward, were to a great extent fixed in the earliest periods by the condition and nature of the earth's crust. They have had their laws of growth, involving consequent features, as much as organic structures. In this remark, we refer not, under the term continent, to the surfaces of land bounded by the water line; for these, by slight subsidences, are greatly varied in form and size:—but to those extended areas, which, were there no water, would stand raised far above the intermediate oceanic depressions.

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* In this Journal, Vol. xlv, p. 111, (1843,) the writer has supported the principle that metamorphic changes require no other cause but what attends submarine igneous action, and that the word *hypogene* applied to such rocks is inadmissible. The views there presented properly include not only the heat from submarine volcanic action and fissure ejections, but that escape of heat, going on for ages, through the fractures attending the gradual folding and uplifting of strata while beneath the sea. Similar views, of earlier date, are offered by De la Beche, in his very able Report on Cornwall, Devon and W. Somerset, 8vo, 1839. The de-bituminization of the anthracite coal of the Appalachians appears to be attributed by Prof. Rogers essentially to this cause. (Trans. Assoc. Amer. Geol. and Nat., 1840–1842, p. 473.)

4. Metamorphism—the heat according [illegible] various metamorphic changes.*

V. Earthquakes, or a vibration of the earth's crust, caused by agency, internal or external, and causing vibrations of the sea besides other effects. (Ib. 176.)

VI. Effects in geological history. (Ib. 187.)

VII. Courses of mountains and ocean lakes, and general form of continents, determined to a great extent by the general direction of the earth's cleavage structure, and the position of the large areas of greatest contraction.

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* In this Journal, Vol. XL, p. 11[illegible], (1841) the writer has expressed the principle [illegible]

Prof. Wyman —
with the kind regards of
James D. Dana